ARS SPECIAL REPORT

Breeding Better Beef Cattle Through Performance Testing

ARS 22-62

November 1960

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

FOREWORD

A number of economically important traits, which can be measured in beef cattle, have proved to be highly heritable. There is a substantial range among animals in any breeding herd in such traits as birth and weaning weights, rate of gain, feedlot efficiency, and several carcass characters. Research has shown that these are, to a considerable extent, inherited differences. By recording the performance of individual cattle, either on the farm or in a testing station, it has become practical to choose breeding animals which excel in these important traits and can make the greatest improvement in the future herd. This report outlines current knowledge on the subject and points out practical courses of action.

Information in this report was provided by the Animal Husbandry Research Division of the Agricultural Research Service

BREEDING BETTER BEEF CATTLE THROUGH PERFORMANCE TESTING

Performance testing offers beef cattle breeders a way of discovering and measuring differences among animals in their inherited abilities to grow rapidly, mature early, use feed efficiently, develop the kinds of carcasses that are preferred by packers and consumers, and reproduce regularly. Thus, close attention to performance can give cattlemen the means of improving their herds and their profits.

Research has demonstrated a high degree of heritability of several of these traits in beef cattle. Also, research has shown that when cattle are kept under nearly equal conditions and their performance records are adjusted for known environmental differences, genetically superior animals can be identified.

Herd improvement based on records of performance tends to be permanent. Each time performance records are exploited in breeding for a new generation, an increment of productivity, quality, or both is added to the herd. Substantial herd improvement can be made in as few as 10 to 20 years.

HOW PERFORMANCE TESTING FITS TODAY'S NEEDS AND OPPORTUNITIES

Performance testing can help cattlemen meet today's needs for more and better beef.

U. S. population not only is booming upward, meaning more mouths to feed, but each person is tending to eat more beef than ever before. At the same time, cattlemen are faced with continually rising production costs.

These facts give great significance to research results that have shown that selecting breeding cattle with higher weaning weights, and postweaning rates of gain results in calves superior in these traits. Such calves require, during their lifetimes to slaughter weight, less feed per unit of gain, less labor per animal, and a shorter tie-up of a producer's capital.

More limited studies of heritability of beef carcass characters have shown that selecting cattle for higher carcass quality has the potential of producing beef that is leaner, and at the same time more tender, and more flavorful--all features that appeal to consumers.

This aspect of performance testing is bound to grow in importance in the years ahead. A number of large handlers of beef are now buying their supplies under specification that the carcasses must meet certain standards. Specifications call for correctly finished carcasses within certain fairly low dressed-weight ranges, a limited amount of fat in relation to lean meat, a certain carcass grade, and a stated high proportion of the

carcass to be in preferred cuts. The trend is toward greater leanness. And tenderness is certain to be specified as we develop fast but reliable means of testing this.

The improvements that can be made through performance testing more than compensate for the effort of testing.

HISTORIC EXPERIENCE IN BREEDING BEEF CATTLE

Our early cattle were durable--able to withstand difficult conditions. But these animals also were lean, long-legged, rangy, and slow in maturing. Their meat was probably tough by today's standards.

As conditions for managing livestock improved, American cattlemen sought to improve market qualities. Purebreds of the three most popular British beef breeds had many desired maket qualities and were introduced into this country in large numbers late in the last century and used to grade up the existing native cattle. Those breeds finished well and in a shorter time in the feedlot.

However, as time has passed, it has become apparent that in many cases a higher than desired proportion of the carcass weight of these cattle is represented by fat. American breeders, during the past 50 years or more have selected for some other features, such as extreme depth of chest, middle, and flank. These were mistakenly valued and carefully perpetuated through breeding. Present data indicate that in extreme form this resulted in a large proportion of brisket and other low-priced cuts without any beneficial effect on production efficiency.

Notwithstanding some adverse developments, our cattle have probably improved substantially in genetic value during the past three-quarters of a century. Our cattle industry has made a number of other gains, too. Through the improvement of nutrition, disease and parasite control, and management, and a shift from dairy and dual-purpose types to the more desired beef type, cattlemen are today producing beef more efficiently. In 40 years the national average feed required to produce 100 pounds of beef has decreased from 1,076 pounds to 915 pounds of corn or its equivalent in other feeds. Over the past 30 years beef production per head of cattle has increased 43 percent and, in conjunction with a 44-percent rise in cattle numbers, has actually doubled total production. This has greatly improved the national diet. During the past 20 to 30 years average per capita consumption of beef has increased about 43 percent and consumers are putting only a slightly higher percentage of total disposable income into the purchase of beef. These facts indicate that the industry has done an outstanding job of producing beef that people like and are eager to buy.

While the main stream of experience has been toward more economical beef, there have been some reverse currents, too. From time to time certain fads and fancies became associated with cattle breeding and diverted breeders from their central purposes of producing beef more efficiently and producing superior beef.

One of the earliest fads was the worship of favored bloodlines. Once an animal won renown in the show ring, his progenies through many generations would be favored for breeding, regardless of their merits. This fad persists to a degree.

Worship of the short, low, thick-body form reached extremes within the past quarter century in the breeding by many cattlemen of strains variously known as "Comprests" or "Compacts." These were small, short-boned and short-legged, thick, light-finishing strains of animals that originated through gene mutations. Research showed that they had no carcass advantage over the conventional type, but did have the disadvantages of producing less beef per head and at greater overhead cost. The serious problem of hereditary dwarfism which arose in several breeds about 10 to 15 years ago, largely put an end to whatever interest there had been in breeding for ultra-small types.

EVOLUTION OF A NEW CONCEPT

Around 1930, before we knew anything specific about heritability of most beef cattle characters, scientists started developing procedures or methods of measuring important traits in beef cattle. It is, however, only within the past 15 years that we have developed detailed knowledge of the influence of heredity on growth rate, efficiency of gain, and quality of product. The first known estimates of heritability of a number of important characters were made in 1946, based on data from the beef research herd at Miles City, Mont.

Since that time numerous studies at several ARS and State agricultural experiment stations have shown (1) that beef cattle differ in inherent productivity for several important traits, (2) that these differences are fairly high in heritability, (3) that rate and efficiency of gain are rather highly correlated, and (4) that brood-cow performance is important to the total economy of beef production and is a repeatable trait.

During the past decade, the Agricultural Extension Service has developed on-the-farm performance testing programs in 42 States based on these facts. In these States, Extension specialists and county agents assist the herd owners in weighing and grading their calves, and in processing the records during the demonstration stages of the program.

The Extension Service has helped the participating cattlemen in 17 States to organize beef cattle improvement associations. In time, these associations will take over the service aspects of the program. But it will be necessary for extension workers to continue to provide educational assistance in teaching herd owners to analyze their records and to use them in their breeding programs.

An international organization, formed in the U. S. in 1955, records and recognizes weaning weights and post-weaning gains of beef cattle of all breeds.

Several national breed associations of both long-established and newer breeds have taken steps to make performance records of their cattle a matter of official record. In most cases these associations work very closely with State groups.

Emphasis in both the associations and in the Extension programs has been on testing procedures in which cattle performance is measured under conditions prevailing on the individual farm or ranch. With practically all programs, weights and grades of calves at weaning are recorded. Most programs also obtain data on growth of animals to a year or more of age.

In most cases, weights and other data are obtained on the farm and sent to a central office and are there adjusted for environmental effects. Detailed reports are made on each herd and each animal in it. Summary reports covering all animals in the association also are often furnished to members so they can compare their own records with the association averages. Since many member cattlemen don't have livestock scales, some of the associations provide portable scales. Extension workers and other authorized personnel score the calves for conformation and supervise the weighing.

In addition to on-the-farm testing programs, there has been considerable interest in central testing stations for evaluating post-weaning gaining ability of cattle from several herds at one location under standard conditions. Because of the costs, most animals tested in central stations have been bulls. Although there are not enough stations to test an appreciable fraction of the Nation's bulls, central test stations can serve a useful function in permitting comparisons of animals from different herds under equal conditions. If these comparisons are to be valid, certain conditions must be met. These include (1) testing a large enough sample from each herd to be meaningful, (2) taking precautions to minimize effects of pretest environment on test gains, and (3) considering test gains in relation to preweaning gains rather than separately. To be most effective central test stations supplement rather than replace on-the-farm test programs. In some States bulls are admitted to central test stations only if they have had satisfactory records in a preweaning farm evaluation.

Research information on heritability of carcass traits has evolved only recently and, to date, little organized testing is being done by breeders for carcass traits. This is a logical next step and a few associations are now considering a slaughter and carcass-evaluation service for groups of steers by given sires. This phase of the program will doubtless be broadened when we perfect our methods for measuring carcass traits in live animals.

While the organizations have encouraged performance testing and are particularly helpful to small breeders, many medium to large cattle breeders have found they can do their own testing following recommendations of research and extension workers.

Regardless of whether a breeder is in an organized State Extension or breed-association performance-testing program or does his own testing, the decisions on which animals to use for breeding are his own. Since each decision influences future genetic value of his herd, a breeder's success depends on the skill and judgment with which he selects animals with the inherent genetic constitution to meet future demands. Since four or five or more characters must always be considered in a breeding program, compromises and judgment are always necessary in using records. It is seldom that a single animal will be superior in every important trait. Thus, performance test records are no substitute for skill and judgment. Rather, they increase the fund of information which the skilled breeder can use to improve accuracy of selections.

HERITABILITY OF THE IMPORTANT CHARACTERS

The performance that breeders are interested in is a combination of growth characteristics, economy of gain, quality of product and regular

reproduction. All of the economically important characters related to growth, efficiency of gain, live-animal scores, and carcass traits so far studied appear to have heritabilities high enough for selection to be effective. In experimental herds, approximately the following percentages of the variation in the indicated characters have been found to be due to heredity:

Character	Average heritability	Character	Average heritability
Production factors:	(Percent)	Live-animal scores:	(Percent)
Birth weight	41	At weaning	27
Weaning weight	29	At 18 months off grass	27
Dam's nursing ability	40	At slaughter	44
Post-weaning feedlot gain	47		
Efficiency of feedlot gain	40	Carcass traits:	
Final feedlot weight	69	Dressing percent	71
Post-weaning pasture gain	34	Carcass grade	32
Cancer-eye susceptibility	32	Size of rib-eye	69
		Tenderness (shear test)	58

These findings were made over the past 12 to 14 years by USDA and 36 cooperating State agricultural experiment stations.

Some of these characters that a breeder can easily test for are weaning weight, feedlot gain, final feedlot weight, and pasture gain. All these characters are medium to high in heritability.

The term heritability represents the percent of the total variation in a trait that on the average is due to hereditary differences which will respond to selection. The remainder is due to random or undetected differences in environment. For example, a 500-pound weaned calf in a herd with a 400-pound average will on the average transmit factors for about 29 pounds greater weaning weight to his offspring in the first generation. That's 29 percent (see chart) of the individual's 100-pound superiority over the herd average.

The heritability estimates are high enough for most characters to warrant selecting a bull for breeding on the basis of his record for tested characters rather than waiting until his sons and daughters have demonstrated his genetic potential. Occasionally, progenies don't live up to expectations, and the sire or dam will have to be dropped from the breeding program. Other breeding animals may, however, do even better than their records suggest.

Since selection must be for several traits at once, overall progress in a breeding program will depend upon the genetic correlations between traits, that is, what effect selection for one trait will have on another. Knowledge of these relationships is still incomplete but in several cases it appears that, fortunately, there are positive rather than antagonistic correlations. For example, several studies indicate a positive genetic relationship between growth rates at various stages, showing that selection for size or growth at one stage will lead to some improvement at other stages. For the growth comparisons to be valid, however, all animals

must have equal environmental opportunity--equal temperatures, equal handling and equal feed--or adjustments must be made to compensate for inequalities.

While it is possible to individually feed bulls to evaluate their efficiency of gain, the tests are costly and difficult to conduct. As a result, tests of gaining efficiency have been limited mostly to agricultural experiment stations. Fortunately, there is a positive relationship between rate and efficiency of gain in cattle fed to similar final weights and degree of finish. The Minnesota Station and ARS, very early in beef cattle breeding research, found that 70 to 80 percent of the total variation in efficiency of gain can be accounted for if rate of gain is known. These and other studies show a high enough relation between rate of gain and efficiency of gain for the former to be a good indication of the latter. Recently an ARS-State study in Virginia showed that each quarter-pound increase in average daily gain saves about 47 pounds of total digestible nutrients per hundred pounds of gain made by bulls or steers on full feed for 168 to 200 days following weaning. Fast-gaining cattle represent savings in handling and overhead costs, but their lower requirement of feed is by far their greatest asset.

Heritability estimates for carcass traits are based on much less data than those of other traits, so there's much less certainty of their actual size. The high estimates obtained thus far, however, indicate substantial possibilities for modifying carcass characteristics through breeding. Most carcass traits must be determined on carcasses after slaughter. This means that selection has to be based on carcass qualities of an animal's sibs or progeny rather than directly on the animal itself. It has been estimated that progress can be only 1/5 to 1/4 as fast as if direct measurements could be made on live animals. Studies to date indicate that correlations between production traits and carcass quality are too low for any worthwhile carcass improvement to be made indirectly as a result of selecting for production traits. Conversely, this means that cattlemen can select for production and carcass traits concurrently without either adversely affecting the other.

In other cases there may be negative relationships which will hinder progress. One study suggested a low negative relationship between nursing ability of cows and inherent gaining ability of their calves. Further study on this question is needed, but to date the relationship does not appear strong enough to seriously hinder concurrent-selection progress for both nursing ability and gaining ability. It does, however, indicate that selection should be for both things. Undue emphasis either on ability to gain when nursing foster mothers or on post-weaning gaining ability could well lead to loss of nursing ability.

Some important traits are probably not subject to improvement by selection. Fertility, as measured by percent of calf crop raised, has one of the greatest influences on herd profit, but is little influenced by heredity and greatly affected by nutrition, management, and control of diseases and parasites.

Selection experiments with beef cattle have not been underway long enough for researchers to demonstrate the progress which can be made over long periods of time. Calculations based on heritability, the selection differentials which are possible, and reproductive rates permit estimates of probable progress. For example, if information were complete on all

animals in a population, if selection were for one trait only, and if mass selection based on individual records and records of sibs were practiced, the following annual improvements appear possible:

Weaning weight	4.3 pounds increase
Daily gain in feedlot	.043 pound increase
Feed per hundred pounds gain	8.4 pounds decrease
Rib-eye area	.029 square inch increase
Tenderness (shear test)	.088 pound less force

These rates of improvement could be increased by 50 to 150 percent in large populations by progeny-testing sires, and by making extensive use of the superior ones through artificial insemination. The greatest increase in rate of improvement would be in carcass traits for which individual evaluation of breeding animals is not now possible. It should be emphasized that these are changes which could be attributed to genetic improvement. Actual changes could be more or less if management or feeding either improved or deteriorated.

Selection for weaning weight and post-weaning gaining ability look particularly promising. Information on these is easy to get. Over a 10-year period, the simplest forms of mass selection in the population at large have the potential of improving weaning weight by 10 percent, or 43 pounds, and daily gain by 15 to 20 percent, or .43 pound.

The foregoing examples may be useful in cases where marked deficiencies in one trait make it advisable to select for it alone for a time. But single-trait selection can rarely be justified. Rather, concurrent selection for several characters will nearly always be a more practical plan for most herds. The larger the number of traits selected for, the slower the progress with any one of them. Average reductions in progress will be about $\frac{1}{\sqrt{n}}$ where n is the number of traits selected for. Thus, for example, concurrent selection for four traits would be expected to reduce progress for any one by about 1/2. Selection for economically unimportant "fancy points," such as many conformation scorecards contain, reduces the intensity of selection for other points. This emphasizes the importance of selecting for few items, and only for characters of economic importance with high enough degrees of heritability for selection to be effective.

Concurrent selection for four independent traits would reduce progress for any one of them by half, but if the traits were equally important economically and all heritable, improvement in total merit would be much greater than if selection were limited to any one trait. The studies show, for example, that in 10 years one such plan could increase average weaning weight by 21 pounds, average daily gain on feed by 0.21 pound, and rib-eye area by 0.13 square inch, and would reduce by 0.44 pound the shear force required to cut the meat in a standard tenderness test.

Improvements of this magnitude would represent improvement of about 5 percent in weaning weight over present industry averages and would be largely a net increase since costs of cow maintenance would be little affected. The increase in average daily gain probably would save 6 to 8 percent in feed during a normal fattening period. While not revolutionary or spectacular in any one year, these gains in production factors obviously are important in the long run. Changes in carcass traits would be in desired directions but of lesser magnitude. Increased emphasis on carcass

traits should expedite their improvement, but would necessarily mean less-intense selection and less progress for the production traits.

If such improvements were made nationwide, they would have a real impact on the efficiency of the industry. While these estimates appear realistic on the basis of present data, it must be emphasized that the estimates are yet to be confirmed by long-time testing.

FUTURE PROSPECTS

The tendency to breed for imagined values in crops and livestock is fast giving way to the principle of breeding for characters of known, measurable economic importance. When breeders turned their backs on the shape of the corn ear and some of the unimportant conformation points of the hen and the dairy cow in favor of performance records, they very quickly made far-reaching and rapid improvements. Similar progress can be expected with beef cattle, for regardless of the form that performance testing takes, selection will be for traits of known economic importance.

Just how much progress can be made is yet to be determined. Current studies should tell us how long selection and breeding for various specific traits can be continued without deterioration of other traits. It may soon be known whether selections made in one environment will be reliable for animals to be used in other areas. One specific case where this is important is in determining just how widely the best bulls of a region can be used for artificial insemination in other areas.

The greater intensity of selection which can be practiced in sires if the superior ones are extensively used in artificial insemination makes this technique of great potential importance in improving performance of beef cattle. It is now used to a considerable extent in purebred or seedstock herds and use in commercial herds is growing although still limited to a very small percentage of the Nation's total beef cows. The problems of detecting beef cows in heat, getting them to corrals for insemination, and conception rate are considerable in beef cattle. It is thus uncertain at this time how general the practice may become. Use of superior sires in artificial insemination has a great genetic potential if the practical problems listed above can be overcome.

One of the best prospects for raising per-capita consumption of beef depends on carcass improvement. Yet slowness of progress in carcass improvement is perhaps the greatest single problem in using performance testing programs. Carcass traits must now be measured after slaughter. Some genetic progress is possible from basing selection for carcass traits of brothers and sisters. Selecting on the basis of progeny carcasses is more accurate and permits greater selection intensity, but delays final selection for the bull at least 2 years. Much more rapid progress could be made if accurate estimates of carcass quality could be made in living animals and the superior individuals used for breeding purposes. Available techniques are not very useful but research is active and some current experiments hold promise of giving us carcass tests for use directly on the young animals that are to be compared.

An instrument (tenderness press) developed by ARS for testing biopsy specimens of flesh from the living calf is giving us tenderness measures that correlate quite well with standard meat tests for tenderness. A small

specimen can be taken under local anaesthetic with little disturbance to the animal. The sample is squeezed through a hole in the press; the required force correlates well with the force required with a tenderness shear used after slaughter. It seems to be a reliable test, whether the specimen is fresh or aged, raw or cooked. USDA's Agricultural Marketing Service and several State experiment stations are also experimenting with the test.

The scientists are looking into the possibility of judging flavor from the same biopsy specimen.

A sonic device now under study has also given promising results in evaluating the fat and muscle content of live cattle. The simple and harmless soundings in certain body regions reveal how much lean flesh there is in important carcass areas. Manual probing in certain areas gives some indication of body proportions and fat-lean ratio but not as well as sonic testing.

If future research confirms the usefulness of these methods, or if other methods are developed, they will improve or replace present methods of conformation scoring and the delayed, indirect testing through sibs and progenies. An early-age evaluation would thus be possible for several important characters which have some of the highest heritabilities. Progress in improving these characters, now slow, might be speeded up several fold. The cattle could be separated early and best handled for their intended use--breeding or fattening for slaughter. And regardless of where they are, bulls with rare abilities for carcass improvement could be found early by these tests and channeled into breeding programs where they would be most useful.

In retrospect, there's rather good evidence that performance testing can give cattlemen, the industry, and the Nation some important benefits. Genetic change is rather slow, but, in time, its effect on the beef industry is likely to be revolutionary. If any industry is to survive and prosper, it must supply a product of the quality that people want and at a price they can afford to pay. Properly used, performance testing will help the beef industry do both of these things.

Growth Through Agricultural Progress

U.S. GOVERNMENT PRINTING OFFICE : 1961 O—581531